Benchmarking BeO Thermal Scattering Libraries

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NEA Data Bank

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WPEC 2016 Meetings
SG 42 - Thermal Scattering Kernel S(α,β): Measurement, Evaluation and Application

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Outline

1. Motivation
2. ICSBEP – DICE Search
3. Application case
4. Summary

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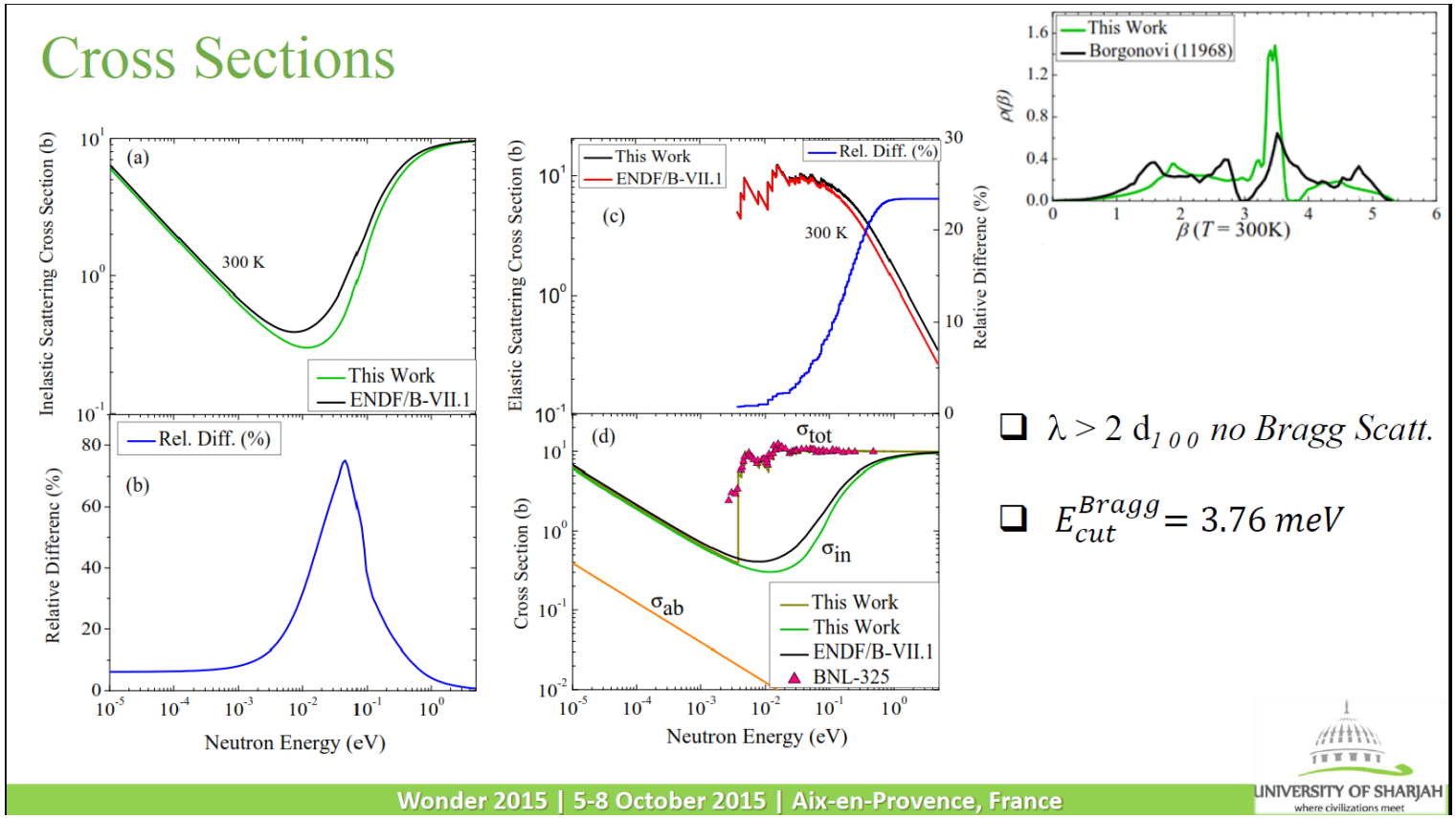
1. Motivation

At WONDER 2016, Iyad Al-Qasir (University of Sharjah, UAE) presented some work on BeO TSL cross section data[1,2]



[1]Presentation: "Thermal Neutron Scattering Cross Section of BeO", Iyad Al-Qasir et al, WONDER 2016.
[2]Annals of Nuclear Energy 87 (2016) 242-251

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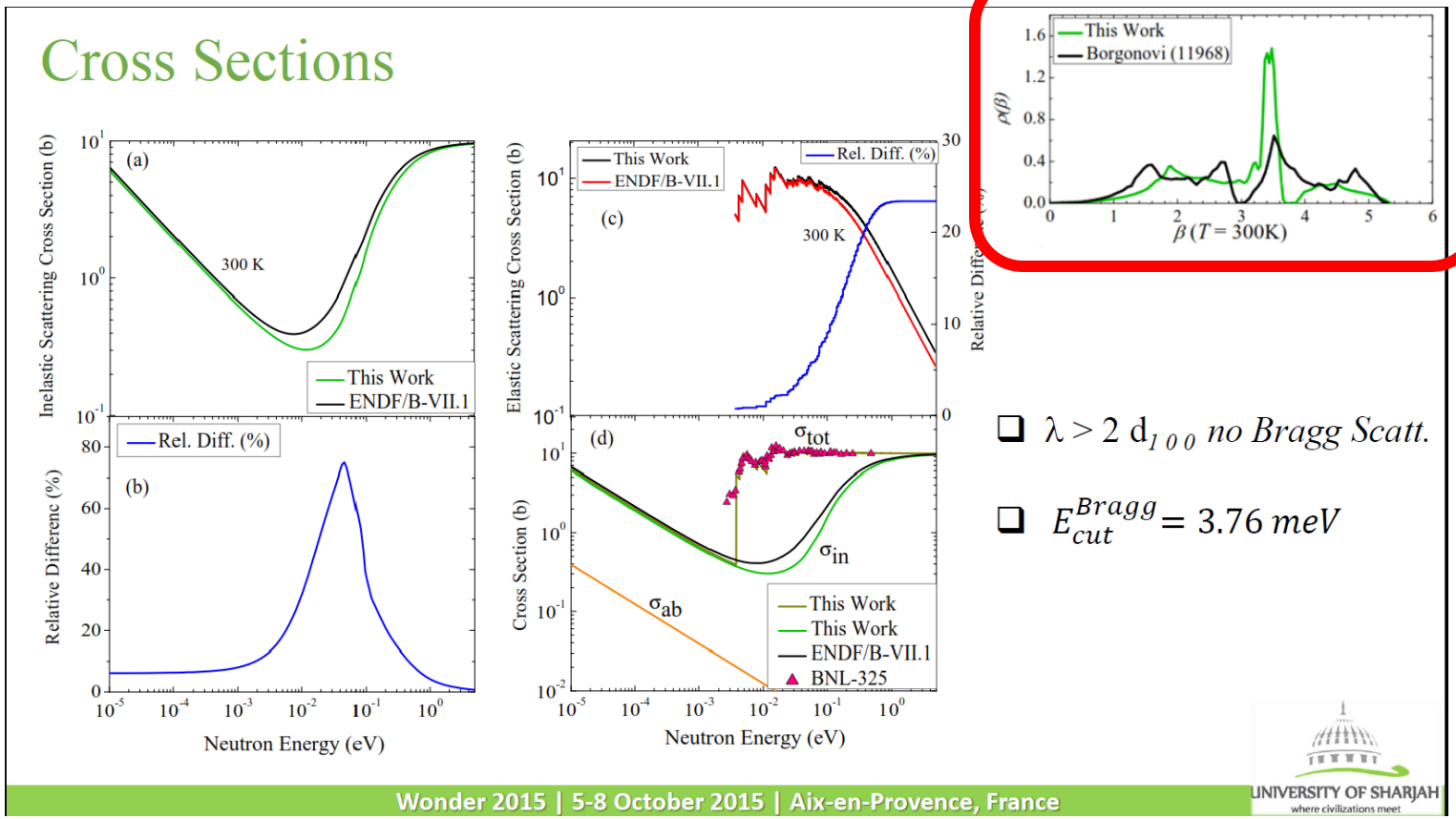
1. Motivation

"the acoustic phonons of the phonon density of states currently used to generate the ENDF libraries are wrong for BeO, as shown by later experimental measurements"



[1]Presentation: "Thermal Neutron Scattering Cross Section of BeO", Iyad Al-Qasir et al, WONDER 2016.
[2]Annals of Nuclear Energy 87 (2016) 242-251

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1. Motivation

ACE files were provided in order to assess the impact of new files on criticality benchmarks

That required:

- ICSBEP – DICE search for benchmark with BeO

- Run benchmark cases and analyse of results

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2. ICSBEP- DICE Search

Search criteria used, independently:

- Title: including “Be”, “Beryllium”, “Beryllium Oxide”, “BeO”
  missed “Beryllium-Oxide”
- Keyword: including “Be”, “BeO”
- Fuel – region: 4 – Be – Beryllium
- Moderator/Coolant material: Be, BeO
- Reflector material: Be, BeO
- Separator material: 4 – Be – Beryllium
- Neutron balance – capture (%) Be (natural)
- Sensitivity to Be

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2. ICSBEP- DICE Search

A list of 57 benchmarks ID were identified → Reviewed one-by-one marking if have BeO → 26 Benchmarks IDs

Benchmark ID with BeO			
#	ID	#	ID
1	HEU-COMP-MIXED-003	14	HEU-MET-INTER-010
2	HEU-COMP-MIXED-004	15	HEU-MET-MIXED-012
3	HEU-COMP-THERM-010	16	HEU-MET-THERM-027
4	HEU-MET-FAST-009	17	HEU-MISC-THERM-002
5	HEU-MET-FAST-010	18	HEU-SOL-THERM-046
6	HEU-MET-FAST-016	19	IEU-SOL-THERM-004
7	HEU-MET-FAST-038	20	MIX-MET-FAST-004
8	HEU-MET-FAST-042	21	PU-MET-FAST-021
9	HEU-MET-FAST-052	22	PU-SOL-THERM-019
10	HEU-MET-FAST-070	23	SUB-HEU-MET-FAST-001
11	HEU-MET-FAST-075	24	SUB-HEU-MET-MIXED-001
12	HEU-MET-FAST-094	25	U233-MET-THERM-001
13	HEU-MET-INTER-009	26	U233-SOL-THERM-007

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2. ICSBEP- DICE Search

26 Benchmarks IDs → Reviewed one-by-one for MCNP inputs → 36 Benchmarks cases with inputs

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
PU-MET-FAST-021							
	PU-MET-FAST-021-001	Be-Reflected	Be (natural)	No			
	PU-MET-FAST-021-002	BeO-Reflected	Be (natural)	Yes	Yes	PDF	Yes
PU-SOL-THERM-019							
	No sensitivities			Yes	No	MORET-APOLLO inputs	No
HEU-MET-FAST-009							
	HEU-MET-FAST-009-001	Be-Reflected	Be (natural)	No	No		
	HEU-MET-FAST-009-002	BeO-Reflected	Be (natural)	Yes	Yes	PDF	Yes
HEU-MET-FAST-010							
	HEU-MET-FAST-010-001	B+Be-Reflected	Be (natural)	No			
	HEU-MET-FAST-010-002	B+BeO-Reflected	Be (natural)	Yes	Yes	PDF	Yes
HEU-MET-FAST-016							
	HEU-MET-FAST-016-001	Be-Reflected	Be (natural)	No			
	HEU-MET-FAST-016-002	BeO-Reflected	Be (natural)	Yes	Yes	PDF	Yes
HEU-MET-FAST-038							
	HEU-MET-FAST-038-001		Be (natural)	Yes	Yes	PDF	Yes
	HEU-MET-FAST-038-002		Be (natural)	Yes	Yes	PDF	yes
HEU-MET-FAST-042							
	HEU-MET-FAST-042-001		Be (natural)	No			
	HEU-MET-FAST-042-002		Be (natural)	Yes	Yes	PDF	yes

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2. ICSBEP- DICE Search

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
HEU-MET-FAST-052							
	HEU-MET-FAST-052-001		Be (natural)	Yes	Yes	PDF	yes
HEU-MET-FAST-070							
	HEU-MET-FAST-070-002	ZPR-9/8	Be9	Yes	Yes	PDF	Yes
HEU-MET-FAST-075							
	HEU-MET-FAST-075-001	ZPPR-20/C	Be9	Yes	Yes	PDF	Yes
HEU-MET-FAST-094							
	HEU-MET-FAST-094-001		Be (natural)	Yes	Yes	PDF	Yes
	HEU-MET-FAST-094-002		Be (natural)	Yes	Yes	PDF	Yes
HEU-MET-INTER-009							
	No sensitivities			Yes	No	Inputs for COG	No
HEU-MET-INTER-010							
	HEU-MET-INTER-010-001	Experiment No. 1	Be9	Yes	No	Inputs for COG	No
HEU-MET-THERM-027							
	HEU-MET-THERM-027-002	Experiment No. 2	Be9	Yes	No	Inputs for COG	No
	HEU-MET-THERM-027-003	Experiment No. 3	Be9				
	HEU-MET-THERM-027-004	Experiment No. 4	Be9				
	HEU-MET-THERM-027-005	Experiment No. 5	Be9				
	HEU-MET-THERM-027-006	Experiment No. 6	Be9				
	HEU-MET-THERM-027-007	Experiment No. 7	Be9				
	HEU-MET-THERM-027-008	Experiment No. 8	Be9				
	HEU-MET-THERM-027-009	Experiment No. 9	Be9				
	HEU-MET-THERM-027-010	Experiment No. 10	Be9				
	HEU-MET-THERM-027-011	Experiment No. 11	Be9				

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2. ICSBEP- DICE Search

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
HEU-MET-MIXED-012							
	HEU-MET-MIXED-012-001	ZPPR-20/D	Be9	Yes	Yes	PDF	Yes
HEU-COMP-MIXED-003							
	HEU-COMP-MIXED-003-001		Be9	Yes	Yes	PDF	Yes
	HEU-COMP-MIXED-003-002		Be9	Yes	No		
	HEU-COMP-MIXED-003-003		Be9	Yes	No		
	HEU-COMP-MIXED-003-004		Be9	Yes	No		
	HEU-COMP-MIXED-003-006		Be9	Yes	No		
HEU-COMP-MIXED-004							
	HEU-COMP-MIXED-004-001		Be9	Yes	No - only MCU	PDF	
	HEU-COMP-MIXED-004-002		Be9	Yes	No - only MCU	PDF	
	HEU-COMP-MIXED-004-003		Be9	Yes	No - only MCU	PDF	
	HEU-COMP-MIXED-004-004		Be9	Yes	No - only MCU	PDF	
	HEU-COMP-MIXED-004-005		Be9	Yes	No - only MCU	PDF	

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2. ICSBEP- DICE Search

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
HEU-COMP-THERM-010							
	HEU-COMP-THERM-010-001		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-002		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-003		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-004		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-005		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-006		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-007		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-008		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-009		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-010		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-011		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-012		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-013		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-014		Be (natural)	Yes	Yes	DVD	Yes
	HEU-COMP-THERM-010-015			Yes	Yes	PDF	Yes
	HEU-COMP-THERM-010-016		Be (natural)	Yes	No		
	HEU-COMP-THERM-010-017		Be (natural)	Yes	No		
	HEU-COMP-THERM-010-018		Be (natural)	Yes	No		
	HEU-COMP-THERM-010-019		Be (natural)	Yes	No		
HEU-MISC-THERM-002							
	HEU-MISC-THERM-002-020		Be (natural)	Yes	No		
	HEU-MISC-THERM-002-021		Be (natural)	Yes	Yes	PDF	Yes
HEU-SOL-THERM-046							
	No sensitivities			Yes	No	MORET-APOLLO inputs	No
IEU-SOL-THERM-004							
	No sensitivities			Yes	Yes	PDF	Yes

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2. ICSBEP- DICE Search

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
U233-MET-THERM-001							
	No sensitivities			Yes	Yes	dvd	Yes
U233-SOL-THERM-007							
	No sensitivities	Only one case (1)		Yes	Yes	PDF	Yes
MIX-MET-FAST-004							
	MIX-MET-FAST-004-001	Be Reflected	Be9	No			
	MIX-MET-FAST-004-002	BeO Reflected	Be9	Yes	Yes	PDF	Yes
SUB-HEU-MET-FAST-001							
	SUB-HEU-MET-FAST-001-001	ZPPR-20/E	Be9	Yes	Yes	dvd	Yes
SUB-HEU-MET-MIXED-001							
	SUB-HEU-MET-MIXED-001-001	ZPPR-20/D	Be9	Yes	Yes	dvd	Yes

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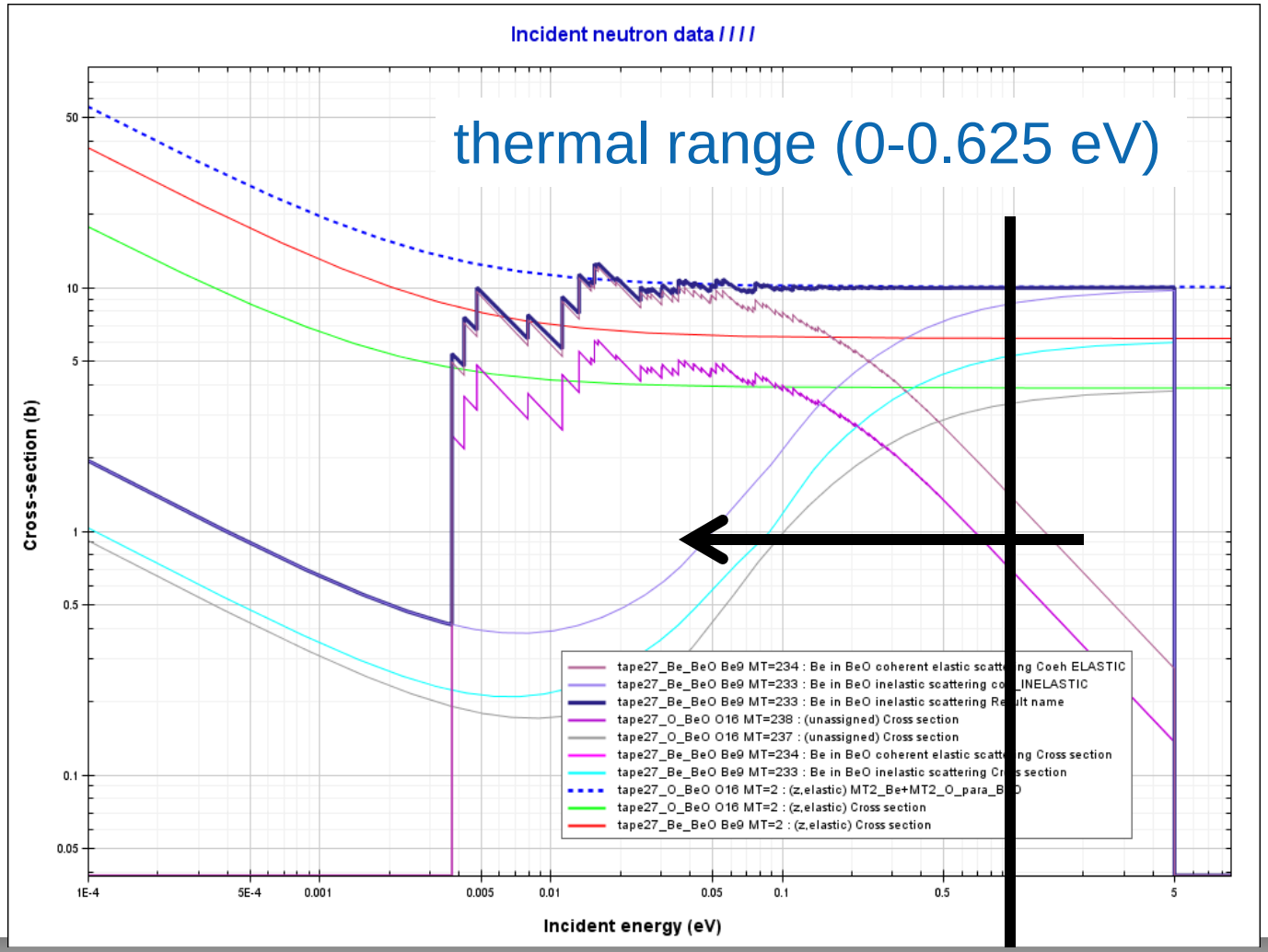
2. ICSBEP- DICE Search

In which energy range shall we look for sensitivities?



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2. ICSBEP- DICE Search

Sorted by total (abs) sensitivity in thermal range (0-0.625 eV)

		keff Sensitivity (%/%) 0 - 0.625 eV				
#	Benchmark Case	Capture	Elastic	Total	Total (abs)	MCNP input?
1	HEU-MET-THERM-027-011	-0.04347	0.15867	0.1152	0.20214	No
2	HEU-MET-THERM-027-009	-0.02398	0.13543	0.11145	0.15941	No
3	HEU-MET-THERM-027-010	-0.02652	0.10669	0.08018	0.13321	No
4	HEU-MET-THERM-027-007	-0.02112	0.10894	0.08781	0.13006	No
5	HEU-MET-THERM-027-008	-0.02399	0.10313	0.07914	0.12712	No
6	HEU-MET-THERM-027-005	-0.01357	0.08137	0.0678	0.09494	No
7	HEU-MET-THERM-027-006	-0.0158	0.07227	0.05646	0.08807	No
8	HEU-MET-THERM-027-004	-0.01142	0.06884	0.05742	0.08026	No
9	HEU-MET-THERM-027-003	-0.00708	0.04367	0.0366	0.05075	No
10	HEU-MET-THERM-027-002	-0.00552	0.03631	0.03079	0.04183	No
11	HEU-MET-INTER-010-001	-0.00234	0.02011	0.01777	0.02245	No
12	HEU-COMP-MIXED-003-001	-0.00038	0.01441	0.01403	0.01479	Yes
13	HEU-COMP-MIXED-003-006	-0.00064	0.01356	0.01291	0.01420	No
14	HEU-COMP-MIXED-003-004	-0.00049	0.01109	0.0106	0.01158	No
15	HEU-COMP-MIXED-003-003	-0.00061	0.01031	0.0097	0.01092	No
16	SUB-HEU-MET-FAST-001-001	-0.00006	-0.00263	-0.00269	0.00269	Yes
17	HEU-COMP-THERM-010-013	-0.00013	0.00121	0.00107	0.00134	Yes
18	HEU-COMP-THERM-010-012	-0.00014	0.00113	0.00099	0.00127	Yes

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2. ICSBEP- DICE Search

Sorted by total (abs) sensitivity in thermal range (0-0.625 eV)

		keff Sensitivity (%/%) 0 - 0.625 eV				
#	Benchmark Case	Capture	Elastic	Total	Total (abs)	MCNP input?
1	HEU-MET-THERM-027-011	-0.04347	0.15867	0.1152	0.20[illegible]	No
2	HEU-MET-THERM-027-009	-0.02398	0.13543	0.11145		No
3	HEU-MET-THERM-027-010	-0.02652	0.10669	0.08[illegible]		No
4	HEU-MET-THERM-027-007	-0.02112	0.1089[illegible]		.13006	No
5	HEU-MET-THERM-027-008	-0.02399	0	[illegible]	0.12712	No
6	HEU-MET-THERM-027-005	-0.01[illegible]		0.0678	0.09494	No
7	HEU-MET-THERM-027-006		.227	0.05646	0.08807	No
8	HEU-MET-THERM-027-004		0.06884	0.05742	0.08026	No
9	HEU-MET-THERM-027-003	.00708	0.04367	0.0366	0.05075	No
10	HEU-MET-THERM-027-002	-0.00552	0.03631	0.03079	0.04183	No
11	HEU-MET-INTER-010-001	-0.00234	0.02011	0.01777	0.02245	No
12	HEU-COMP-MIXED-003-001	-0.00038	0.01441	0.01403	0.01479	Yes
13	HEU-COMP-MIXED-003-006	-0.00064	0.01356	0.01291	0.01420	No
14	HEU-COMP-MIXED-003-004	-0.00049	0.01109	0.0106	0.01158	No
15	HEU-COMP-MIXED-003-003	-0.00061	0.01031	0.0097	0.01092	No
16	SUB-HEU-MET-FAST-001-001	-0.00006	-0.00263	-0.00269	0.00269	Yes
17	HEU-COMP-THERM-010-013	-0.00013	0.00121	0.00107	0.00134	Yes
18	HEU-COMP-THERM-010-012	-0.00014	0.00113	0.00099	0.00127	Yes

COG inputs

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2. ICSBEP- DICE Search

Sorted by total (abs) sensitivity in thermal range (0-0.625 eV)

		keff Sensitivity (%/%) 0 - 0.625 eV				
#	Benchmark Case	Capture	Elastic	Total	Total (abs)	MCNP input?
19	HEU-COMP-THERM-010-014	-0.00014	0.00103	0.00089	0.00117	Yes
20	HEU-COMP-THERM-010-019	-0.00013	0.00104	0.00091	0.00117	No
21	HEU-COMP-THERM-010-010	-0.00014	0.00102	0.00088	0.00116	Yes
22	HEU-COMP-THERM-010-011	-0.00013	0.001	0.00086	0.00113	Yes
23	HEU-MISC-THERM-002-021	-0.00012	0.00098	0.00086	0.00110	Yes
24	HEU-MET-MIXED-012-001	-0.00011	-0.00093	-0.00103	0.00104	Yes
25	HEU-COMP-THERM-010-018	-0.00013	0.00088	0.00074	0.00101	No
26	SUB-HEU-MET-MIXED-001-001	-0.00013	-0.00087	-0.001	0.00100	Yes
27	HEU-COMP-THERM-010-017	-0.00013	0.00083	0.0007	0.00096	No
28	HEU-COMP-THERM-010-007	-0.00014	0.00082	0.00068	0.00096	Yes
29	HEU-COMP-THERM-010-016	-0.00013	0.00082	0.00069	0.00095	No
30	HEU-COMP-THERM-010-005	-0.00014	0.00077	0.00063	0.00091	Yes
31	HEU-COMP-THERM-010-008	-0.00013	0.00077	0.00064	0.00090	Yes
32	HEU-COMP-THERM-010-009	-0.00014	0.00076	0.00063	0.00090	Yes
33	HEU-COMP-THERM-010-006	-0.00013	0.00074	0.0006	0.00087	Yes
34	HEU-MISC-THERM-002-020	-0.00012	0.00058	0.00046	0.00070	No
35	HEU-COMP-THERM-010-004	-0.00013	0.00046	0.00033	0.00059	Yes
36	HEU-COMP-THERM-010-003	-0.00013	0.00037	0.00025	0.00050	Yes

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2. ICSBEP- DICE Search

Benchmarks with BeO but no sensitivity data

Benchmark ID	Benchmark Case	Case label	isotope	BeO ??	MCNP inputs	Source	Converted
PU-SOL-THERM-019							
	No sensitivities			Yes	No	MORET-APOLLO inputs	No
HEU-MET-INTER-009							
	No sensitivities			Yes	No	Inputs for COG	No
HEU-SOL-THERM-046							
	No sensitivities			Yes	No	MORET-APOLLO inputs	No
U233-MET-THERM-001							
	No sensitivities			Yes	Yes	dvd	Yes
U233-SOL-THERM-007							
	No sensitivities	Only one case (1)		Yes	Yes	PDF	Yes

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3. Application case

First analysis of BeO files was done with the following benchmarks

Benchmark	keff	exp. Unc.
HEU-COMP-THERM-010-001	1.00000	0.00500
HEU-COMP-THERM-010-002	1.00000	0.00500
HEU-COMP-THERM-010-003	1.00000	0.00500
HEU-COMP-THERM-010-004	1.00000	0.00500
HEU-COMP-THERM-010-005	1.00000	0.00500
HEU-COMP-THERM-010-006	1.00000	0.00500
HEU-COMP-THERM-010-007	1.00000	0.00500
HEU-COMP-THERM-010-008	1.00000	0.00500
HEU-COMP-THERM-010-009	1.00000	0.00500
HEU-COMP-THERM-010-010	1.00000	0.00500
HEU-COMP-THERM-010-011	1.00000	0.00500
HEU-COMP-THERM-010-012	1.00000	0.00500
HEU-COMP-THERM-010-013	1.00000	0.00500
HEU-COMP-THERM-010-014	1.00000	0.00500
HEU-COMP-THERM-010-015	1.00000	0.00500
HEU-MET-FAST-009-002	0.99920	0.00150
HEU-MET-FAST-016-002	0.99960	0.00180
HEU-MET-FAST-038-001	0.99990	0.00070
HEU-MET-FAST-094-001	0.99940	0.00120
HEU-MET-FAST-094-002	0.99930	0.00100
PU-MET-FAST-021-002	1.00000	0.00260
U233-MET-FAST-005-001	1.00000	0.00300
U233-MET-FAST-005-002	1.00000	0.00300

List of BeO TSL files

- beo_beoa99
- beo_beob99
- beo_beoboi
- beo_beobor
- beo_endfb71

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3. Application case

First analysis of BeO files was done with the following benchmarks

Benchmark	keff	exp. Unc.
HEU-COMP-THERM-010-001	1.00000	0.00500
HEU-COMP-THERM-010-002	1.00000	0.00500
HEU-COMP-THERM-010-003	1.00000	0.00500
HEU-COMP-THERM-010-004	1.00000	0.00500
HEU-COMP-THERM-010-005	1.00000	0.00500
HEU-COMP-THERM-010-006	1.00000	0.00500
HEU-COMP-THERM-010-007	1.00000	0.00500
HEU-COMP-THERM-010-008	1.00000	0.00500
HEU-COMP-THERM-010-009	1.00000	0.00500
HEU-COMP-THERM-010-010	1.00000	0.00500
HEU-COMP-THERM-010-011	1.00000	0.00500
HEU-COMP-THERM-010-012	1.00000	0.00500
HEU-COMP-THERM-010-013	1.00000	0.00500
HEU-COMP-THERM-010-014	1.00000	0.00500
HEU-COMP-THERM-010-015	1.00000	0.00500
HEU-MET-FAST-009-002	0.99920	0.00150
HEU-MET-FAST-016-002	0.99960	0.00180
HEU-MET-FAST-038-001	0.99990	0.00070
HEU-MET-FAST-094-001	0.99940	0.00120
HEU-MET-FAST-094-002	0.99930	0.00100
PU-MET-FAST-021-002	1.00000	0.00260
U233-MET-FAST-005-001	1.00000	0.00300
U233-MET-FAST-005-002	1.00000	0.00300

Benchmarks of interest (highest sensitivity to Be in thermal range)

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3. Application case

First analysis of BeO files was done with the following benchmarks

Benchmark	keff	exp. Unc.
HEU-COMP-THERM-010-001	1.00000	0.00500
HEU-COMP-THERM-010-002	1.00000	0.00500
HEU-COMP-THERM-010-003	1.00000	0.00500
HEU-COMP-THERM-010-004	1.00000	0.00500
HEU-COMP-THERM-010-005	1.00000	0.00500
HEU-COMP-THERM-010-006	1.00000	0.00500
HEU-COMP-THERM-010-007	1.00000	0.00500
HEU-COMP-THERM-010-008	1.00000	0.00500
HEU-COMP-THERM-010-009	1.00000	0.00500
HEU-COMP-THERM-010-010	1.00000	0.00500
HEU-COMP-THERM-010-011	1.00000	0.00500
HEU-COMP-THERM-010-012	1.00000	0.00500
HEU-COMP-THERM-010-013	1.00000	0.00500
HEU-COMP-THERM-010-014	1.00000	0.00500
HEU-COMP-THERM-010-015	1.00000	0.00500
HEU-MET-FAST-009-002	0.99920	0.00150
HEU-MET-FAST-016-002	0.99960	0.00180
HEU-MET-FAST-038-001	0.99990	0.00070
HEU-MET-FAST-094-001	0.99940	0.00120
HEU-MET-FAST-094-002	0.99930	0.00100
PU-MET-FAST-021-002	1.00000	0.00260
U233-MET-FAST-005-001	1.00000	0.00300
U233-MET-FAST-005-002	1.00000	0.00300

Benchmarks of interest (highest sensitivity to Be in thermal range)

Benchmarks with very low sensitivity to Be in thermal range -> Introduce noise …

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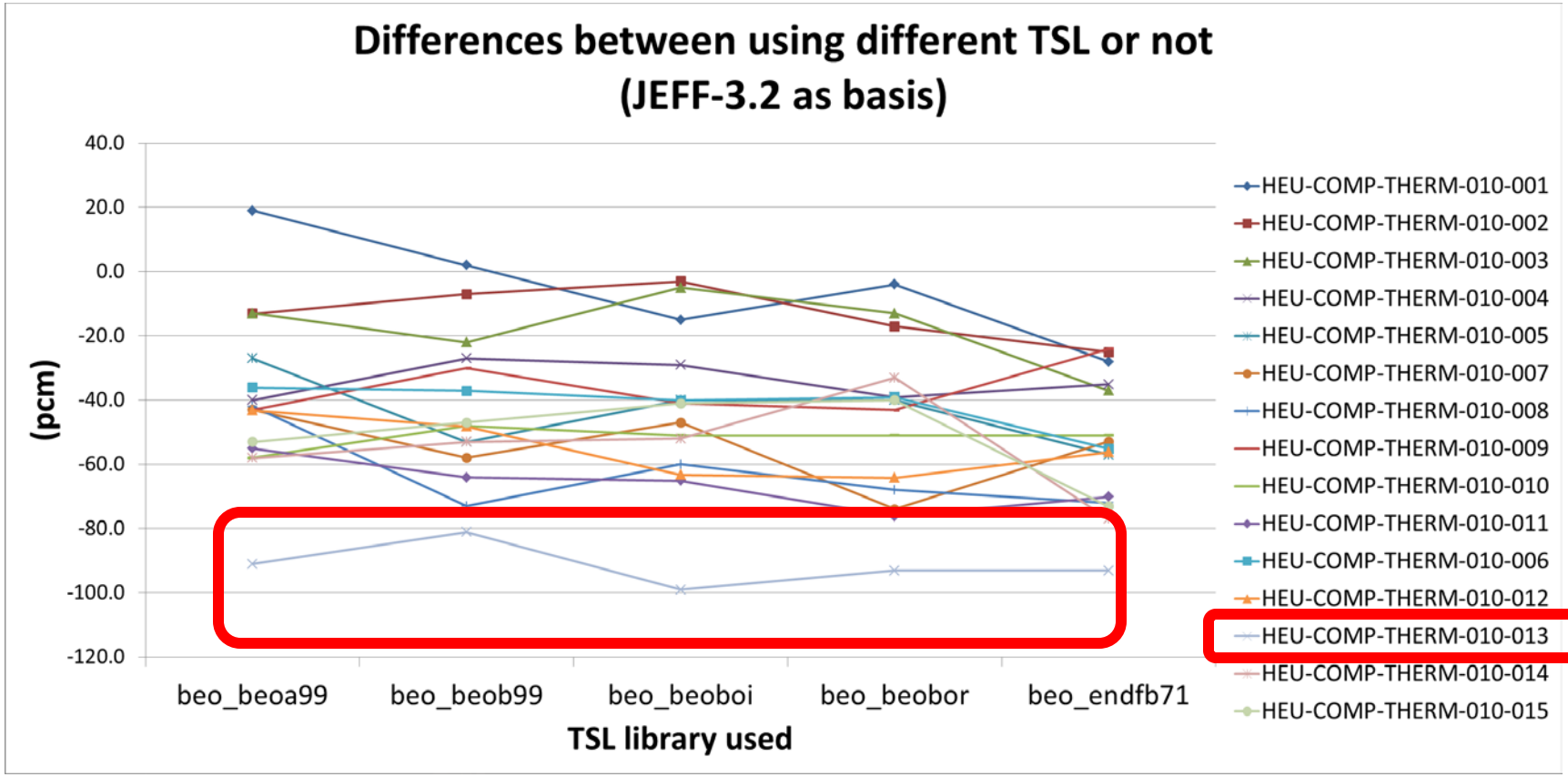
3. Application case

Comparison of using or not BeO TSL in MCNP inputs



- Corresponds to benchmark with the highest sensitivity to Be

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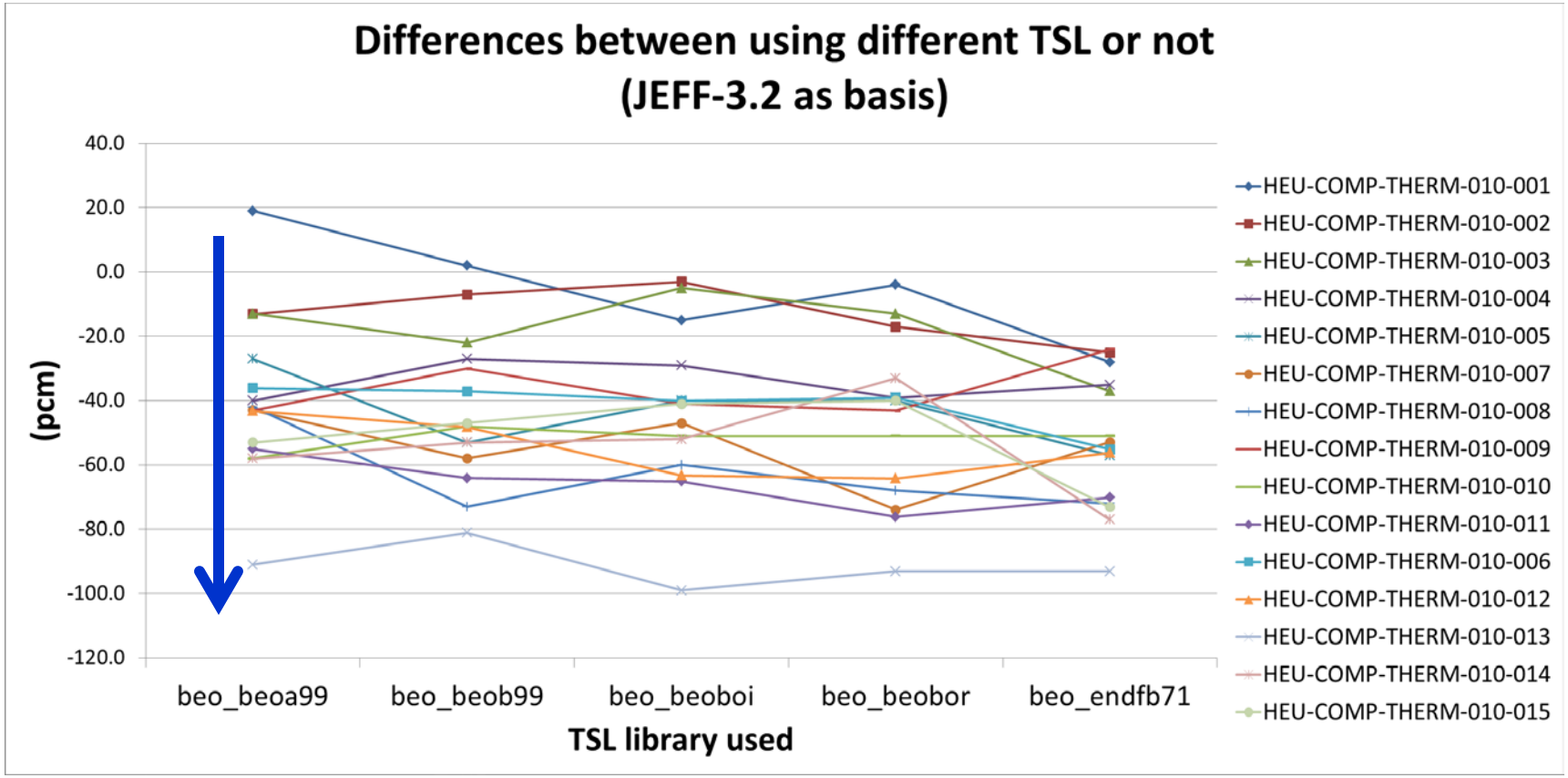
3. Application case

Comparison of using or not BeO TSL in MCNP inputs



- Not using BeO TSL induces higher Keff values
- MCNP calculations with 10 pcm statistical uncertainty

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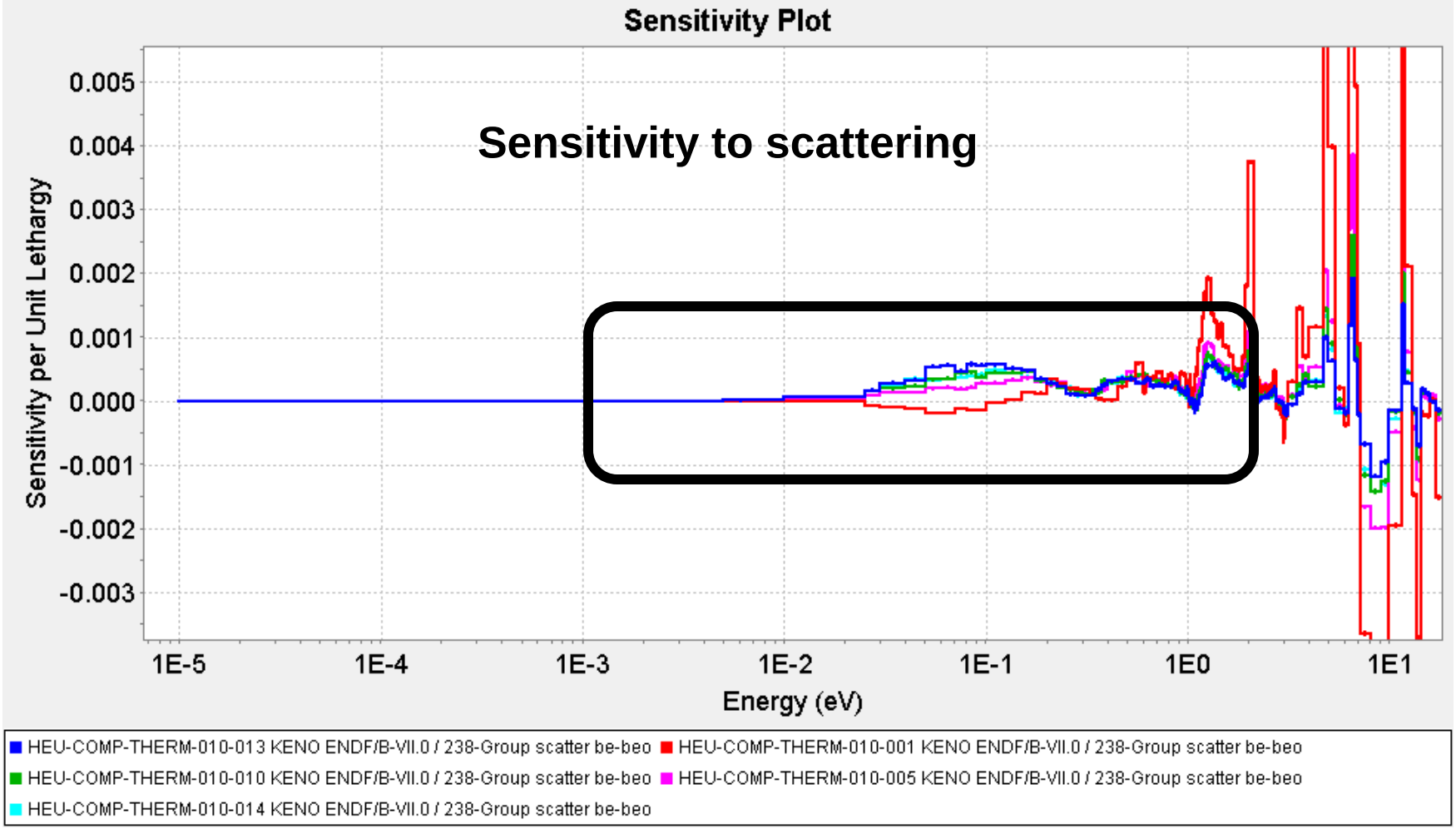
3. Application case



Very low sensitivity to scattering for HEU-COMP-THERM-010, even being the ones with largest sensitivities

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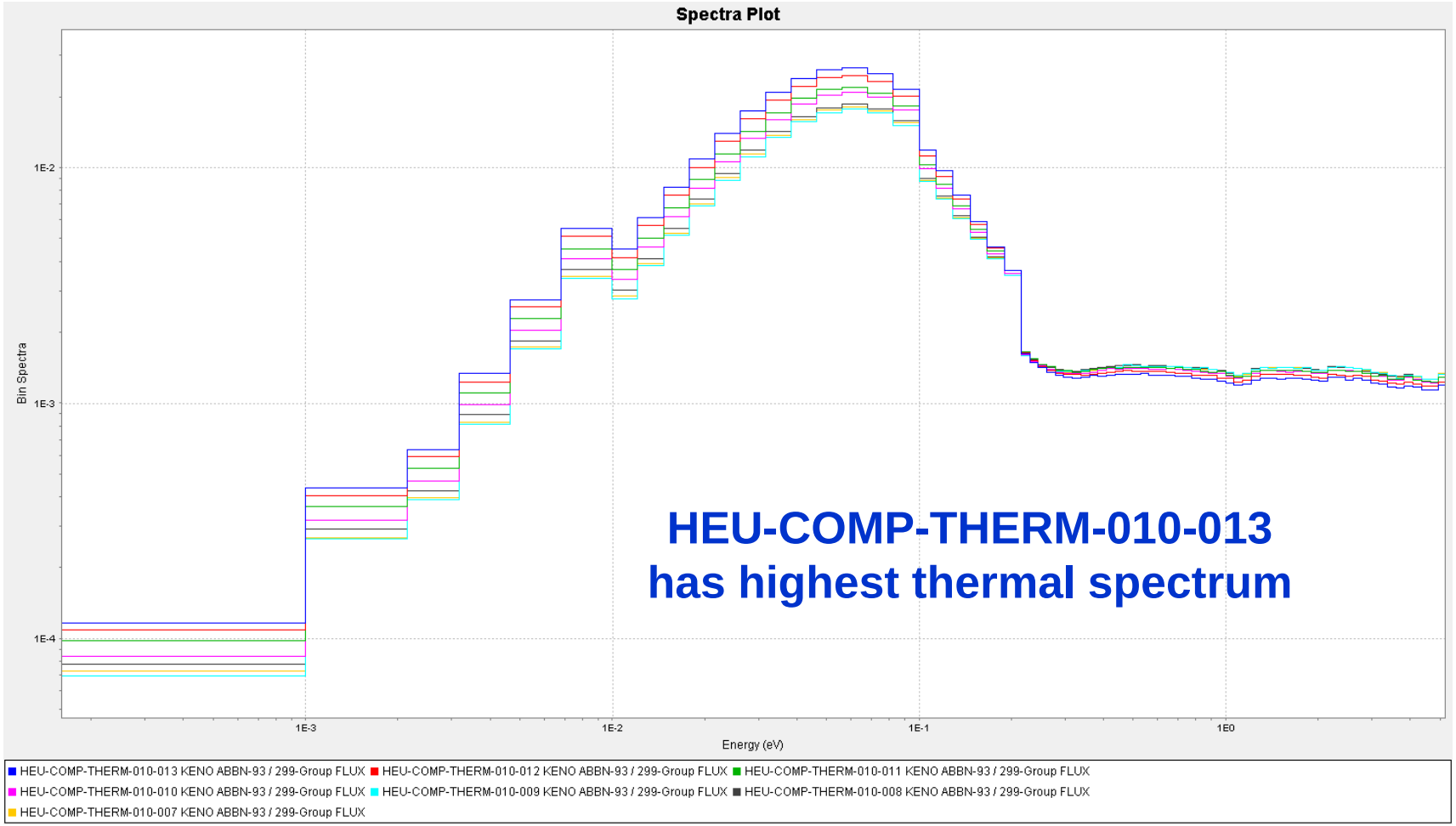
3. Application case



HEU-COMP-THERM-010 spectra

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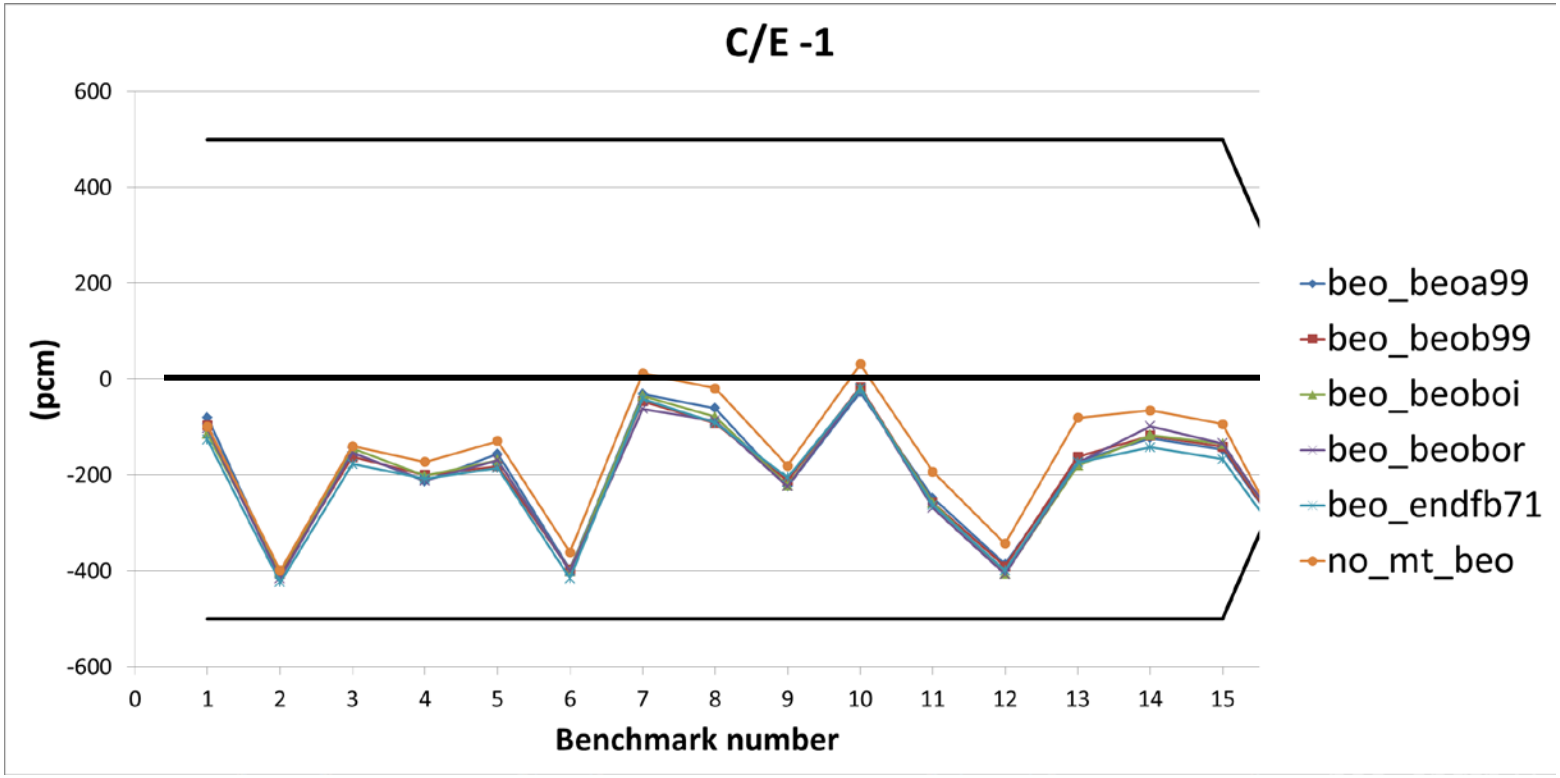
3. Application case

Comparing C/E values for different BeO TSL libs



HEU-COMP-THERM-010

- better to not include BeO TSL data, at least when using JEFF-3.2 ??

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4. Summary

Selection and identification of relevant benchmarks with BeO

- **Identified in ICSBEP – DICE all benchmarks with BeO**
- **Benchmarks ranked by sensitivity to Be in thermal range (0-0.625 eV)**
- **Benchmarks with BeO and having MCNP inputs identified**

  Inputs for other codes are provided: mainly COG / MCU / KENO

  -> Possibility of translating from code to another?

First analysis

- **Importance of HEU-COMP-THERM-010 cases corroborated**
- **Including BeO TSL seems to not improve the agreement (when using JEFF-3.2 as basis)**

Future work

- **Expand the analysis to benchmarks identified with MCNP inputs ?**
- **Use other nuclear data libraries as basis (e.g. ENDF/B-VII.1 or JENDL-4.0) ?**

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Thank you for your attention!!
Gracias por su atención!!

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2. ICSBEP- DICE Search

Sorted by total (abs) sensitivity in thermal range (0-0.625 eV)

		keff Sensitivity (%/%) 0 - 0.625 eV				
#	Benchmark Case	Capture	Elastic	Total	Total (abs)	MCNP input?
37	HEU-MET-FAST-075-001	-0.00002	-0.00047	-0.00048	0.00049	Yes
38	HEU-MET-FAST-070-002	-0.00012	-0.00027	-0.00039	0.00039	Yes
39	HEU-COMP-THERM-010-002	-0.00011	0.00012	0	0.00023	Yes
40	HEU-COMP-THERM-010-001	-0.00011	0.00007	-0.00005	0.00018	Yes
41	HEU-COMP-MIXED-004-005	-0.00004	0.0001	0.00006	0.00014	No
42	PU-MET-FAST-021-002	-0.00001	0.00013	0.00012	0.00014	Yes
43	HEU-COMP-MIXED-003-002	-0.00004	0.00009	0.00005	0.00013	No
44	HEU-COMP-MIXED-004-003	-0.00004	0.00009	0.00005	0.00013	No
45	HEU-MET-FAST-094-001	-0.00004	-0.00006	-0.00009	0.00010	Yes
46	HEU-COMP-MIXED-004-004	-0.00004	-0.00004	-0.00008	0.00008	No
47	HEU-COMP-MIXED-004-001	-0.00004	-0.00003	-0.00006	0.00007	No
48	HEU-MET-FAST-042-002	-0.00001	0.00006	0.00005	0.00007	Yes
49	HEU-COMP-MIXED-004-002	-0.00004	0.00002	-0.00002	0.00006	No
50	HEU-MET-FAST-016-002	-0.00001	0.00003	0.00002	0.00004	Yes
51	HEU-MET-FAST-038-002	0	0.00004	0.00002	0.00004	Yes
52	HEU-MET-FAST-038-001	0	-0.00002	-0.00002	0.00002	Yes
53	HEU-MET-FAST-052-001	-0.00001	0	-0.00001	0.00001	Yes
54	HEU-MET-FAST-009-002	0	0	0	0.00000	Yes
55	HEU-MET-FAST-010-002	0	0	0	0.00000	Yes
56	HEU-MET-FAST-094-002	0	0	0	0.00000	Yes
57	MIX-MET-FAST-004-002	0	0	0	0.00000	Yes

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